

ENGINEERS' REPORT  
FOR SUPPLYING THE  
CITY OF ROCHESTER  
WITH  
WATER  
FROM  
VARIOUS SOURCES,  
MADE TO THE  
Directors of the Rochester Water Works Co.  
BY  
STUART & MARSH,  
CIVIL ENGINEERS.

NEW YORK, OCTOBER 1<sup>ST</sup>, 1853.

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## R E P O R T .

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SOURCES of pure water, from which the CITY OF ROCHESTER can be abundantly supplied, are either so distant as to render the works required to convey it, by the force of gravity, to the tops of the highest houses in the City, quite expensive, or else so low as to involve a large and constant expense to elevate it to the necessary height for proper distribution. At various times Hemlock, Honeoye, and Canadice lakes, and their outlets, Caledonia Springs, Allen's Creek, the Genesee River, and Lake Ontario, have each been suggested as a source from which a supply, both suitable in quality and ample in quantity, could be drawn, for the present and future wants of your flourishing and beautiful city.

It is proposed to show in this Report some considerations and facts as to the feasibility of adopting some one or more of these sources of supply for your present and future wants, the urgent demand for immediate action, and to examine the mode by which this great *desideratum* may be best attained.

The long residence of the undersigned in your city in past years, and professional engagements in connection with

the State Works, have afforded us very many opportunities to become acquainted with localities in the city and surrounding country, and an intimate knowledge of the character and extent of the lakes, rivers, and other water courses that so plentifully abound in Western New York. It is quite fortunate that this is so, otherwise it would not have been possible for us to have presented the results embodied in this hurried Report, within the *six* weeks' time allowed, in which to make the surveys of the several proposed routes, and prepare the maps, plans, and report for the consideration of the Company.

Remembering, as citizens, the lamentable deficiency, both in the *quality* and *quantity* of water for family and other necessary uses, we have entered upon this interesting investigation, deeply sensible of the important duties devolving upon us, and only anxious so to illustrate it as to secure the united and vigorous action of your intelligent citizens and energetic City Councils, in carrying out a plan that will give your city, for all future time, an ample supply of *pure and wholesome water*.

#### SOURCE OF SUPPLY.

With much truth has it been said, that "the varied practical purposes of domestic life to which **PURE WATER** is alone applicable, and the intimate connection of many of these purposes with the health, life, and well-being of humanity, at once attest the high importance of an *abun-*

*dance and excellence* of this vital liquid, for every congregation or community of human beings. The means, therefore, of obtaining, treating, and economizing it, are among the most important objects of human art. The works of the engineer must be regulated by considerations of the available methods of securing ample water supply and efficient drainage; and these considerations will present themselves with that imperative character which they derive from the public will, and which cannot be counterbalanced by any scruples of private economy, or any opposition of corporate prejudice.

“All water at our command for practical use, is more or less impure. Thus, rain-water contains ammonia, and sea-water a variety of salts; whilst the water from lakes rivers, springs, and wells, contains various kinds of impurities, and these impurities are dispelled only by a compound process, or rather a series of processes, by which such matters as are mechanically suspended in the water are allowed to subside, or are arrested by filtering media, and the chemical impurities are absorbed and withdrawn by suitable agents.” As all the earthy, animal, and vegetable matters with which water becomes charged, are extracted from the soil through which or the surfaces over which it passes, it follows that the nature of these matters depends upon the constituents of the soil which is percolated, the amount of them will be in proportion to the time during which the water is maintained in communication with the soil, modified, of course, by the degree in which they may be adapted for mutual action. “Thus,” remarks Professor Silliman, “the geological character of a country will in a great measure determine the character of the stream flowing through it. It must be remembered

that water is one of the most *powerful solvents* known to chemists; and that it cannot fall upon the surface of the earth without becoming impregnated, to some extent, with the soluble matters of the rocks and soils over which it runs. A careful analysis of the waters of a given region may enable an acute chemist to judge with considerable certainty of the mineral nature of the country, from what he finds *in its waters*. In a limestone region, we look principally for lime and magnesia in the natural waters, and have little reason to expect the presence of many other ingredients which are found in the various minerals of a primitive country. The waters of a limestone region are *generally hard*, or at least, not so soft as those of a granite region. The quality of hardness is one of great importance to be known, and is owing usually, and I believe I may say always, to the presence of soluble salts of lime and magnesia in the water. Soap forms an insoluble lime compound—lime-soap—in hard waters, which fills the water with a white, curdy precipitate, harsh to the touch, and a serious impediment to the use of the water for many domestic purposes. Perhaps no single character is of more importance to be known than that of the *hardness* or the reverse of a natural water."

Rochester being located on a high table of carboniferous, lime-rock formation, there are but few springs, and those are highly charged with the mineral through which they pass. The finding, therefore, of any considerable supply of *soft* water is impossible; as those excellent springs having their sources in primitive mountains, cannot find their way to a high table of secondary rock.

The well-water now used to supply mostly the city, is

not only *hard*, with a few unimportant exceptions, but also very impure and unfit for domestic use, as will appear from an examination of the analysis, given below, of several wells taken from different localities in the town.

The Table also shows the amount of solid matter *in one gallon of water*, from the various sources mentioned, from wells, lakes, and rivers, at home and abroad.

		Grs. Solid Matter.
LONDON . . .	{ Thames River, . . . . .	28.000
	New     " . . . . .	19.200
PARIS . . . .	Artesian Well, . . . . .	9.860
NEW YORK . .	{ Croton, . . . . .	6.998
	Manhattan Well, . . . . .	125.000
	Avg. several City Wells, . . . . .	58.000
ALBANY . . . .	{ Lydius St. Well, . . . . .	19.240
	Old State House, . . . . .	36.000
	At Exchange, . . . . .	64.680
	Capitol Park, . . . . .	65.520
	Hudson River, . . . . .	6.320
TROY . . . .	Mohawk " . . . . .	7.880
BROOKLYN . .	Avg. Long Island Ponds, . . . . .	2.367
	Corner Gold & Nassau Streets, . . . . .	38.400
	"     High & Jay     " . . . . .	58.640
do Well Water	"     Fulton & Washington St., . . . . .	46.440
	"     Douglas & Smith St., . . . . .	76.960
	Opposite Mansion House, Hicks St., . . . . .	43.200
	Union St. near Columbia, . . . . .	11.760
BOSTON . . . .	{ Cochituate Lake, . . . . .	1.850
	Well, Beacon Hill, . . . . .	50.055
	"     Tremont Street, . . . . .	26.600
	"     At Longaere, . . . . .	56.800
BRIDGEPORT, Ct.	Pequomock River, . . . . .	0.992
PHILADELPHIA.	Schuylkill " . . . . .	4.260
ROCHESTER . .	{ Well, North Fitzhugh Street, . . . . .	26.000
	"     South     do     " . . . . .	16.740
	"     North Washington, . . . . .	34.110
	"     3d Ward House, Cornhill, . . . . .	41.000
	"     East Avenue, near Gibbs St. . . . .	32.160

As early as 1838, the then Mayor of Rochester urged upon the Common Council the necessity of supplying the city with pure water, and recommended the pumping of it from the river into reservoirs, and filtering it before distribution to the inhabitants.

He also, in his report, alludes to the supply from wells, and says, "How much of the sickness and disease of our city arises from its filth, and impurity of its water, it is impossible to tell; but when we reflect that within its narrow compass near 20,000 individuals are inclosed, and that their only water is that which they draw from the common level beneath their feet, we are at once inclined to believe that very much of our disease has its cause here. An abundance of good water promotes health, not only by its domestic use, but by contributing to the general cleanliness of the city, by purifying the atmosphere, cleansing the streets, yards, and sewers, and washing off and conveying to the river and lake the dirt and filth necessarily attending a crowded population."

If this was a true picture fifteen years ago, how much more truthful now, with a population *double* in numbers, and your *sources of supply* necessarily much more impure, as well-water must degenerate as the inhabitants become more dense, and the impurities are collected on or under the surface, and unavoidably penetrate into these wells, and gradually drain and drip to the bottom. This is the case in every rapidly-growing city, as is evidenced by every-day observation, and the experience of all the large towns in this country and Europe. The table already given shows this very conclusively, and the opinion of many eminent physicians confirms it.

Some twenty years ago, several of the most able and

experienced physicians of Boston were called upon for their opinions relative to the injurious effects the use of the well-water of that city had upon the health of its inhabitants; and, as their conclusions were quite unanimous, and aroused the citizens to the necessity of supplying themselves with *better* water, a few extracts from their able Report may not be inappropriate here.

Dr. Warren says, "I can state as a result to be relied on, that the water commonly used from our *city wells*, is apt to produce and to maintain disorders of the stomach and digestive organs, and that there are cases of these affections which *cannot be removed* so long as its use is continued."

"In several cases of obstinate and long-standing affections of the stomach and bowels, I have directed the patients to use *soft* water, instead of *hard well-water*, and have been satisfied that the change has produced a very favorable effect."—*Dr. Hayward.*

"I believe the water from the wells is in a great degree unwholesome, predisposing some to calculous and others to biliary disorders. The *rain-water* is not fit for use. The soot and other impurities on the roofs thicken it, and the leaves dye it in such a way that it will hardly do to wash with. I have been a resident in Boston more than a third of a century, and the population has tripled during that time. The water has very much deteriorated within that time. A spring very soft, and affording much water, at the upper part of Old Temple street, has become *hard*, and the water much diminished. The public well in Scott's Court, that thirty years ago produced excellent water, is

*unfit for use.* The same may be said of other public wells."

—Dr. Shurtleff.

"I am not possessed of any proof that the inhabitants have actually sickened from bad water; still it is my firm belief, that the supply of water is deficient both in quality and quantity. Let the people have a full supply, as pure as furnished by the mountain stream—provided such water can be found and conveyed to the city, within its convenient means—with the addition of pure air; and all is done that men can do, to prevent *epidemic disease*. Putting aside human life and human comfort, one sweeping epidemic may injure the property of the city to a greater amount than the entire cost of an aqueduct to supply the city with pure water."—Dr. Shattuck.

Having seen what the *present* sources of supply are, we turn our attention to those for the *future*, and find the *quality* of the waters proposed to be according to the following careful analysis made from specimens selected this month from the localities named:—

SOLID CONTENTS IN ONE GALLON OF WATER.

No. 1. From foot of Hemlock Lake, . . . . .	$1.\frac{330}{100}$	grains.
" 2. " " Honeoye " . . . . .	4.	"
" 3. " Lake Ontario (the day after a severe storm,) 1000 feet from shore, and west of piers,	$4.\frac{160}{100}$	"
" 4. " Lake Ontario, in front of piers on the same day as above, and half a mile out in lake,	10.	"
" 5. " Honeoye Outlet, 1 mile south of Honeoye Falls, . . . . .	$4.\frac{310}{100}$	"
" 6. " Honeoye Outlet at West Rush (with lime),	$6.\frac{130}{100}$	"
" 7. " Genesee River, at Wolcott's Dam, . . . .	$11.\frac{210}{100}$	"

From the above it appears that No. 1, is *very pure* and the water is *soft*, as also that of No. 2 and No. 5.

The day immediately following a severe storm and rain was taken, as the most suitable, to procure the water from Lake Ontario, as it would be at that period the most affected by the Genesee River. This river does not at once mingle with the lake waters, but flows directly out from the piers, or, according to the direction of the wind, either to the eastward or westward, while the prevailing direction of the current is to the east.

During a storm, and for one or more days after it, the waters of this lake, for the distance of half a mile from the shore, are quite turbid, but soon become transparent and pure. This or similar water is used or is contemplated for use, at Detroit, Cleveland, Buffalo, Oswego, and Montreal, and in each instance by artificial elevation. From this source, an abundant supply of pure and wholesome water would be undoubted for all time.

No. 6, from the Honeoye Outlet at West Rush, contains nearly one-third more solid contents than that from the same outlet several miles farther up the stream (near Smithtown), and is, in addition, strongly impregnated with *lime*, having passed over lime rock in its descent from the Honeoye Falls, and also taken in the streams of the intermediate country, which are not only much *harder* than those of the Hemlock and Honeoye lakes, but also more impregnated with the wash of the several villages bordering the outlet below the Falls, and the neighboring country, and are, consequently, more liable to impurities from rains and floods than the waters nearer the fountain head or lake reservoirs.

The last number (seven), from the Genesee River at the dam near Mount Hope, is of course the most objectionable in its quality, especially on account of its being strongly impregnated with lime, by its own natural flow over a limestone formation for some distance, and by the tributary streams in the vicinity of the city. At seasons of floods much sediment is contained in its waters, which renders it unfit for domestic use, without allowing it to settle in a large receiving reservoir, and then filtering it *thoroughly* before distribution. By a judicious arrangement of these reservoirs, and proper care in their management, its impurities could be arrested, and the water rendered fit for service, as is done at Philadelphia, and other cities where the supply is obtained from rivers.

The cluster of small lakes known as the Hemlock, Honeoye, and the Canadice Lakes, are situated in the counties of Ontario and Livingston, from twenty-six to twenty-eight miles from Rochester, and discharge their waters into the Genesee River (through Honeoye Creek), about fifteen miles south of that city.

From surveys and examinations made of these lakes by the undersigned in 1848, for the State of New York, it was ascertained that they cover an area of 3,846 acres, and receive the drainage of 67,673 acres, as follows :

Hemlock Lake,	area	1,566	acres ;	drains	24,513	acres.
Honeoye	"	1,730	"	"	33,430	"
Canadice	"	550	"	"	9,730	"

The estimated quantity of water that annually falls into these lakes, assumed as twelve inches, or one-third the averaged quantity of rain for a series of years in this State, as reported by the Regents of the University, is as follows :

Hemlock Lake,	1,067,786,280	cubic feet.
Honeoye	“	1,456,210,800
Canadice	“	423,838,800
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Total		2,947,835,880

It is unnecessary to pursue this investigation further to show the vast quantity of water in store in these lakes, from which to draw a full supply for the city; we will, therefore, pass on to inquire into the quality of the water, and the means best adapted to furnish the required quantity by the force of gravity alone, at such an elevation as to reach the tops of the most elevated buildings in Rochester.

#### HEMLOCK LAKE

Is six and one-fourth miles long, and has an average breadth of one hundred and twenty-six rods. The shores are bold, giving generally about eight feet of water at four rods out, and the hills on either side of it rise from the water's edge by steep acclivities, and attain an elevation of over two hundred feet. A swamp occupies the valley at the head of the lake, containing an area of nearly one hundred acres. Immediately south of this small swamp the valley rises rapidly. The soundings at the foot and along the sides of the lake indicate sand, gravel, and clay. At the foot there is a sand beach extending about twenty rods. The level of the water is usually 354 feet above the Erie canal, in Rochester.

#### CANADICE LAKE,

Situated midway between Hemlock and Honeoye lakes, receives the drainage of a much more limited area, and is the

smallest of the three, being only about three miles in length, with an average breadth of eighty-eight rods. The inlet is small, the lake being copiously fed by springs; and the hills on its sides are steep and high. It is also the most elevated, being not less than one hundred feet above Hemlock, and considerably higher than the Honeoye lake. A swamp of about one hundred acres in extent lies at the head of the lake, the surface of which is generally about on a level with it.

#### HONEOYE LAKE.

This lake is over four miles long, and averages about two hundred rods wide. It is by far the most shallow of the two—the greatest depth of water not over thirty feet. The hills on either side are less abrupt than those bordering the Hemlock and Canadice lakes. The inlet is small, and flows through a swamp of seven hundred acres, which occupies the valley at the head of the lake, nearly on a level with the water. The earth generally along the shores is sand, gravel, and blue clay, the last is found in the bed of the lake. Its level above the canal in Rochester is 259 feet.

## PLANS AND COST OF SUPPLY.

FROM the foregoing it appears that a *bountiful supply of pure and wholesome water* is within your reach, from several sources, if the necessary *cost* to convey it to suitable reservoirs and distribute it, is not beyond a prudent expenditure, having reference to the present size and future growth of your city.

This brings us naturally to inquire what *quantity* of water is probably demanded for your present population; and what additional amount will it be prudent to estimate and provide for, within a reasonable future?

The experience of the principal cities of the United States furnishes considerable data for an approximate estimate of the quantity of supply required at present; and this has been assumed at 40 gallons per day to each water taker, the probable number at present being 25,000, increasing to 50,000 twelve years hence. Under this assumption the estimates for the several plans have been based on a present supply of 1,000,000 gallons, providing for an extension to 2,000,000 gallons. The estimates for the several plans presented are limited to the last amount, with the exception of the plan of supply from the outlet south of Honeoye Falls, which is delivered by the force of gravity, and has sufficient head and quantity to allow an increase to 2,500,000 gallons without material increase of cost except for distribution.

By reference to the accompanying maps it will be seen that five several lines have been surveyed and estimated upon: two from Lake Ontario, one from the Genesee River, one from Honeoye outlet, at West Rush, and one from the

outlet south of Honeoye Falls. These, with the exception of the last, involve the use of pumping machinery; the elevation of the city above the lake, and the elevation of the distributing reservoir above the general level of the city, precluding any supply by gravity, except from this source, as will be further seen by reference to the following table of elevations:—

LOCALITIES.	Distance from Rochester.	Above Ontario. Miles.	Above Erie Canal. Feet.
Lower Falls, . . . . .	2	98.00	
Head of Buell avenue, . . . . .	2	208.00	
Lake View, . . . . .	2	279.00	
Erie Canal in Rochester, . . . . .		260.00	
Highest street in " . . . . .		290.00	
Summit, Spring street, . . . . .			18.00
" Washington street. . . . .			20.00
" Sophia " . . . . .			19.00
" St. Paul " . . . . .			24.00
" Court " . . . . .			26.00
" Gibbs and Main, . . . . .			30.00
" East avenue, . . . . .			28.00
Most of Fourth and Sixth Wards, . . . . .			25.00
Third Ward, . . . . .			0 to 20
Seventh " . . . . .			6 to 20
Eighth " . . . . .			10 to 30
Second and parts of First and Ninth Wards, . . . . .			Below
Genesee River Rapids, . . . . .	2		0.00
Allen's Creek, Scottsville, . . . . .	12		22.50
Conesus Outlet, Avon, . . . . .	21		40.00
Honeoye Falls, . . . . .	16		145.00
" Outlet, Smithtown, . . . . .	17		194.00
" Lake, . . . . .	28		259.00
Hemlock Lake, . . . . .	26		354.00
Wadsworth Hill, . . . . .	2		50.00
Ridge west of Mount Hope, . . . . .	2		60.00
" east of " " . . . . .	2		100.00
Hill in east part of Henrietta, . . . . .	6		125.00

The system of supply from the sources above named, have been arranged as follows:

No. 1.—DIRECT LINE FROM LAKE ONTARIO.

This plan contemplates taking the water from Lake Ontario, west of the piers of the Genesee River, where a steam engine will be located, forcing the water to a second engine, situated midway to the Distributing Reservoir, the entire lift being 360 feet, and the distance 8 miles.

The aggregate cost of this supply for the present, for machinery, distribution, &c., will be—

Using Ball's pipe,	584,560 00
“ Cast-iron pipe,	661,960 00
Capital equivalent to annual expense,	155,133 00

Aggregate cost for 2,000,000 gallons' supply:

Using Ball's Pipe,	657,260 00
Using Iron pipe,	768,160 00
Capital equivalent to annual expenses,	311,770 00

No. 2.—CARTHAGE FALLS.

This plan contemplates taking the water from Lake Ontario, and leading it by a supply main to a well at Carthage Falls, whence it will be forced by a water-pressure engine to a tower from which a main will be laid to the distributing reservoir; the length of the supply main being  $6\frac{1}{2}$  miles, and that to the reservoir from the tower 4 miles.

## Aggregate cost for present supply:—

Machinery, Distribution, &c.	• . . . .	\$582,780 00
Using iron pipe,	• . . . .	659,680 00
Capital equivalent to annual expense,	• . . . .	73,000 00

## Aggregate cost for 2,000,000 gallons supply:—

Machinery, Distribution, &c.	• . . . .	\$650,480 00
Using iron pipe,	• . . . .	761,380 00
Capital equivalent to annual expense,	• . . . .	73,000 00

## No. 3.—GENESEE RIVER.

This plan contemplates taking the water of the Genesee River at Wolcott's Dam, and forcing it by steam or water power to the distributing reservoir, distant one mile, the lift being 100 feet, and the available fall  $6\frac{1}{2}$  feet.

## Aggregate cost for present supply:—

Machinery, &c., steam power,	• . . . .	\$243,980 00
Machinery, &c., water power,	• . . . .	263,780 00
Using iron pipe, steam power,	• . . . .	320,880 00
"    "    "    "    water power,	• . . . .	340,680 00
Capital, steam power,	• . . . .	85,166 00
"    water    "	• . . . .	66,916 00

## Aggregate cost for 2,000,000 gallons supply:—

Machinery, &c., steam power,	• . . . .	\$314,680 00
"    water power,	• . . . .	335,480 00
Using iron pipe, steam    "	• . . . .	425,580 00
"    "    water    "	• . . . .	446,380 00
Capital,          steam    "	• . . . .	161,208 00
"    water    "	• . . . .	91,250 00

## No. 4.—HONEOYE OUTLET; WEST RUSH.

This plan contemplates taking the water of the Honeoye Outlet, from the Mill Pond at West Rush, and conducting it by an open canal along the banks of the outlet and the Genesee River to Wolcott's Dam, a distance of thirteen and one-half miles, whence it will be elevated by steam or water power to the distributing reservoir, as per plan No. 3.

Aggregate cost for present supply:—

Canal, Machinery, &c.,	Steam Power,	.. . . .	\$373,980 00
“ “	Water	“ .. . .	393,780 00
Using Iron Pipe,	Steam	“ .. . .	450,880 00
“ “	Water	“ .. . .	470,680 00
Capital,	Steam	“ .. . .	85,166 00
“	Water	“ .. . .	66,916 00

Aggregate cost for 2,000,000 gallons supply:—

Canal, Machinery, &c.,	Steam Power,	.. . . .	\$444,680 00
“ “	Water	“ .. . .	464,400 00
Using Iron Pipe,	Steam	“ .. . .	555,580 00
“ “	Water	“ .. . .	575,380 00
Capital,	Steam	“ .. . .	161,208 00
“	Water	“ .. . .	91,250 00

## No. 5.—HONEOYE OUTLET, SOUTH OF HONEOYE FALLS.

By this plan, the water of this Outlet is taken at Smithtown, a point much nearer its sources and of much greater elevation than any other plan, being 200 ft. above the Erie Canal at Rochester. The water is much purer in quality than at any lower point, as will be seen by the analyses made.

It is proposed to construct an Open Canal for a distance of 8 miles, the intervening distance of  $7\frac{1}{2}$  miles, to the Receiving and Distributing Reservoirs, being of pipe. Provision is also made for a Receiving or Storing Reservoir, not common to any other plan, in which the surplus waters of the Outlet may be collected, so as to be available in the dry seasons, without injuring the supply of the mills on the Outlet. This Reservoir can be conveniently built in the town of Henrietta, four miles from the Distributing Reservoir, and will have a capacity equivalent to a supply of four months.

Aggregate cost for present supply of 1,000,000 gallons:—

Canal, Pipes, Reservoirs, Distribution, &c., . . . . .	\$415,945 00
Using Iron Pipe, . . . . .	492,845 00

Aggregate cost for 2,000,000 gallons supply:—

Canal, Pipes, Reservoirs, &c., . . . . .	\$483,645 00
Using Iron Pipe, . . . . .	594,595 00

This Plan of supply we recommend to your adoption without hesitation.

In addition to the superior quality of the water, it is available without the intervention of forcing machinery and its annual expense, while its supply may be increased, without material cost, far beyond the maximum of the present estimates.

By an additional cost of \$36,000 for Ball & Co.'s pipe, or of \$51,000 for cast-iron pipe, to the several estimates for the present supply, 11 additional miles of distribution may be laid, making 25 miles in all.

<sup>\*</sup>On 41.7 per cent + Ball

## PUMPING MACHINERY.

The calculations for the machinery proposed for the several systems of supply where the use of machinery is required, have been based on a capacity for supplying at least 2,000,000 gallons per day; the formula for friction being that of Hawksley's :

$$P = \frac{q^3 l}{140 d^5} \quad \text{where}$$

$q$ =quantity in gallons per second,

$l$ =length of main in inches,

$d$ =diameter    "       "

The results thus obtained are somewhat in excess, and liberal additions have been made to the forcing power, to provide against contingencies. There are several advantages to be derived from the increased size of the engines, beyond the actual present requirements; as the steam, in the case of the Cornish engines, may be expanded to a greater degree, and the ratio of expansion altered as a greater average pressure is required to do the work. The remarkable success of the Cornish engines is doubtless owing to their use of the principle of expansion to so large an extent. The difference in cost between a large and small cylinder is comparatively trifling; and by providing, at the outset, a cylinder large enough for reasonable prospective use, it is much more convenient and cheap to make the necessary additions of boiler power as circumstances may require; and it is also fully established by theory and practice that large condensers (in condensing engines) are the most effective. With this view, we have preferred to recommend the adoption of engines with large cylinders and appurtenances, by the use of which economy may be consulted at present, with great capacity when

the increase of population requires successive increase of power.

For the system of supply from Lake Ontario, where the head of the Carthage Falls can be made available, we propose to use an engine which, although novel in this country, has proved of great service in the mining districts of Europe, having been more or less used since 1731.

By introducing the supply from a convenient head of water into a cylinder properly arranged, one or more pumps may be worked by a reciprocating, rectilinear motion. The arrangement of the several parts may be changed at will. We propose, however, in this case, to use a direct-acting machine, with a cylinder and pump horizontal, having a common-center line of motion, somewhat similar to Belidor's engine. It will be necessary to provide for an independent valve motion by an auxiliary engine under the same head; but the arrangement of the several parts is quite simple, and the work will be performed with very little attention, and with economical results.

PUMPING MACHINERY FOR DIRECT LINE FROM LAKE ONTARIO  
TO DISTRIBUTING RESERVOIR.

On this line, two Cornish engines will be required, one stationed at the lake, and the other midway to the reservoir, at a distance of *four* miles.

*Duty, &c.*

Lift of each engine, . . . . .	180 ft.
Number of gallons per day, . . . . .	2,000,000
“ “ feet-lbs. per minute, . . . . .	2,000,000
Friction of machinery, . . . . .	400,000
“ “ main, . . . . .	930,600
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Total duty of engine, . . . . .	3,830,600 ft-lbs.

Horse-power of engine, about	100
Stroke of piston and plunger, . . . . .	12 ft.
Number of strokes (single) per minute, . . . . .	14
Diameter of cylinder, . . . . .	50 inches.
"    " plunger, . . . . .	18 "
"    " pump, . . . . .	24 "
Equivalent lift, . . . . .	300 ft.
"    " quantity (per minute) . . . . .	237 cub. ft.
Boiler pressure (per square inch) . . . . .	20 lbs.
Cut-off, "Sickles' Adjustable,"	
Consumption of coal, at present, per day, . . . . .	2.50 tons.
"    " (raising 2,000,000 gals.) per day, . . . . .	5.25 "

#### WATER-PRESSURE ENGINE.—CARTHAGE FALLS.

Direct-acting, the cylinder and pump having a common-center line of motion.

#### *Duty, &c.*

Number of gallons per day, . . . . .	2,000,000
Lift, . . . . .	380 ft.
Force Tube, 30 in. diameter, length . . . . .	450 "
Number of "feet-lbs." per minute, . . . . .	4,222,180
Friction of machinery, . . . . .	422,218
"    Force tube, . . . . .	198,000
<hr/>	
Total duty, . . . . .	4,842,398 ft-lbs.
Horse-power, about . . . . .	147
Stroke of cylinder and pump, . . . . .	10 ft.
Number of double strokes per minute, . . . . .	12
Diameter of cylinder, . . . . .	44 inches.
"    pump, . . . . .	22 "
Available pressure in cylinder, per square inch, . . . . .	43.64 lbs.

Pumping machinery at "Wolcott's" Dam. At this point the power of the water-fall, or a Cornish engine, may be used for forcing the water from the Genesee River to the distributing reservoir, distant one mile, the lift being 100 feet.

#### STEAM ENGINE.

	<i>Duty, &amp;c.</i>
Number of gallons per day, . . . . .	2,000,000
"    " ft-lbs. per minute, . . . . .	1,111,110
Friction of machinery, . . . . .	333,333
"    " Main (30 inches diameter), . . . . .	233,640
<hr/>	
Total duty of engine, . . . . .	1,688,083 ft-lbs.
Horse power of engine, about . . . . .	52
Stroke of piston and plunger, . . . . .	6 ft.
Number of strokes (single) per minute, . . . . .	14
Diameter of cylinder, . . . . .	48 inches.
"    " plunger, . . . . .	24 "
"    " pump, . . . . .	30 "
Equivalent lift, . . . . .	152 ft.
"    " quantity per minute, . . . . .	237 cub. ft.
Boiler pressure per square inch, . . . . .	20 lbs.
Cut-off, "Sickles' adjustable,"	
Consumption of coal, at present, per day, . . . . .	1 $\frac{1}{4}$ tons.
"    " (raising 2,000,000 gals. per day), . . . . .	2 $\frac{3}{4}$ "

NOTE. The expression "feet-lbs." used above, is taken from Weisbach, and signifies the number of pounds raised one foot per minute.

## WATER WHEEL.

For the present supply at "Wolcott's" Dam, the available fall being  $6\frac{1}{2}$  feet, there will be required,

One breast-wheel, diameter, . . . . .	16 feet.
length, . . . . .	15 "
One double-acting pump, stroke, . . . . .	6 "
Number of strokes per minute, . . . . .	10
Diameter of pump, . . . . .	22 inches.

For a supply of 2,000,000 gallons per day, two wheels and pumps of the above size, will be required.

Following are estimates of cost for the several systems of supply:

## ESTIMATES.

## PLAN ONE.

*Direct Line.—Steam Power.*

	1,000,000 gallons. supply.	2,000,000 gallons. supply.
Engine Houses, &c., complete, .	\$35,000 00	\$35,000 00
Machinery and appurtenances, .	392,560 00	397,560 00
Right of way, &c., . . . .	5,000 00	5,000 00
Distributing Reservoir, . . . .	29,900 00	29,900 00
Distribution (cement pipe), .	107,100 00	172,800 00
Engineering, &c., . . . .	15,000 00	17,000 00
	—————	—————
	\$584,560 00	\$657,260 00
Additional cost of cast-iron pipe, .	76,900 00	110,900 00
	—————	—————
	\$661,460 00	\$768,160 00

*Daily Expenses of Steam Power.*

2½ tons coal per day, a \$5, . . . . .	\$12 50
2 Engineers, a \$2, . . . . .	4 00
4 Firemen, a \$1 50, . . . . .	6 00
Oil, Repairs, &c., . . . . .	3 00
	_____
	\$25 50
Capital, at 6 per cent., equal to . . . . .	\$155,133 00

*For supply of 2,000,000 gallons.*

5½ tons coal per day, a \$5, . . . . .	\$26 25
4 Engineers, a \$2, . . . . .	8 00
8 Firemen, a \$1 50, . . . . .	12 00
Oil, Repairs, &c., . . . . .	5 00
	_____
	\$51 25
Capital, at 6 per cent., equal to . . . . .	\$311,770 00

## PLAN TWO.

*Carthage Falls.—Water-Pressure Engine.*

	1,000,000 gallons. supply.	2,000,000 gallons. supply.
Supply main from Lake, &c., . . .	\$152,000 00	\$152,000 00
Engine House, &c., complete, . . .	15,000 00	15,000 00
Machinery and appurtenances, . . .	251,280 00	251,280 00
Water Power, . . . . .	10,000 00	10,000 00
Right of Way, . . . . .	2,500 00	2,500 00
Distributing Reservoir, . . . . .	29,900 00	29,900 00
Distribution, . . . . .	107,100 00	172,800 00
Engineering, &c., . . . . .	15,000 00	17,000 00
	_____	_____
	\$582,780 00	\$650,480 00
Additional cost of cast-iron pipe, . . .	76,900 00	110,900 00
	_____	_____
	\$659,680 00	\$761,380 00

*Daily Expenses of Water-Pressure Engine.*

Oil, Repairs, &c., per day, . . . . .	\$3 00
4 Attendants, . . . . .	7 00
Incidental Expenses, . . . . .	2 00
	_____
	\$12 00
Capital, at 6 per cent., equal to . . . . .	\$73,000 00

## PLAN THREE.

*Wolcott's Dam by steam power, including distribution.*

	1,000,000 gall. supply.	2,000,000 gall. supply.
Engine House, &c. complete, .	\$12,000 00	\$12,000 00
Machinery and appurtenances, .	68,980 00	71,980 00
Right of way, &c. . . . .	1,000 00	1,000 00
Distributing Reservoirs, &c. .	39,900 00	39,900 00
Distribution (Cement pipe), .	107,100 00	172,800 00
Engineering, &c. . . . .	15,000 00	17,000 00
	_____	_____
	\$243,980 00	314,680 00
Additional Cost of Cast-Iron Pipes, .	76,900 00	110,900 00
	_____	_____
	\$320,880 00	\$425,580 00

*Daily expenses at Wolcott's Dam.—Steam Power.*

## 1,000,000 gall. supply.

1½ Tons coal per day, a \$5, . . . . .	\$6 75
1 Engineman, a \$2, . . . . .	2 00
2 Fireman, a \$1 50, . . . . .	3 00
Oil, Repairs, &c., . . . . .	2 25
	_____
	\$14 00

Capital, at 6 per cent., equal to . . . . . \$85,166 00

	2,000,000 <i>galls. supply.</i>	
2½ Tons coal per day, <i>a</i> \$5, . . .	\$13 75	
2 Enginemen, <i>a</i> \$2, . . . .	\$4 00	
4 Firemen, <i>a</i> \$1 50, . . . .	6 00	
Oil, Repairs, &c. . . .	2 75	
		—
		\$26 50
		—
Capital at 6 per cent. equal to . . .		\$161,208 00

### *Wolcott's Dam.—Water Power.*

	1,000,000 <i>galls. supply.</i>	2,000,000 <i>galls. supply.</i>
Pump house, &c., complete, . . .	\$16,000 00	\$16,000 00
Race, Dam, &c. . . .	10,800 00	10,800 00
Machinery and appurtenances, . .	63,980 00	67,980 00
Right of way, &c. . . .	1,000 00	1,000 00
Water power, . . . .	10,000 00	10,000 00
Distributing reservoir, . . .	39,900 00	39,900 00
Distributions (cement pipe), . .	107,100 00	172,800 00
Engineering, &c. . . .	15,000 00	17,000 00
	—	—
	\$263,780 00	335,480 00
Additional cost of cast-iron pipe, . .	76,900 00	110,900 00
	—	—
	\$340,680 00	446,380 00

### *Daily Expenses at Wolcott's Dam.—Breast Wheel.*

	<i>Supply, 1,000,000 gallons.</i>	
Oil, Repairs, &c., per day, . . . .	\$3,00	
Four Attendants, . . . .	6,00	
Incidental Expenses, . . . .	2,00	
	—	
	\$11,00	
Capital at 6 per cent., . . . .		\$66,916 00

*For supply of 2,000,000.*

Oil, Repairs, &c., per day, . . . . .	\$5,00
Four Attendants, . . . . .	6,00
Ineidental Expenses, . . . . .	4,00
	_____
	\$15,00
Capital at 6 per cent. equal to . . . . .	\$91,250,00

PLAN FOUR.

*Steam Power.*

	1,000,000 galls. supply.	2,000,000 galls. supply.
13½ miles open canal, . . . . .	\$120,000	\$120,000
Pumping Engine, House, &c. &c.,	81,980	84,980
Distributing Reservoirs, . . . . .	39,900	39,900
Distribution, . . . . .	107,100	172,800
Engineering and Contingencies, . . . . .	25,000	27,000
	_____	_____
	\$373,980	\$444,680
Additional cost, iron pipe, . . . . .	76,900	110,900
	_____	_____
	\$450,880	\$555,580
Additional cost of water power, . . . . .	19,800	19,800
	_____	_____
	\$470,680	\$565,380

The daily expenditure of raising the water on this plan, will be the same as Plan Three.

PLAN FIVE.

	1,000,000 gals. supply.	2,000,000 gals. supply.
8 miles open canal, . . . . .	\$ 80,300	\$ 80,300
7½ " pipe (20 in. and 16 in.), . . . . .	109,850	109,850
Receiving Reservoir, . . . . .	53,795	53,795
Distributing " . . . . .	39,900	39,900
Distribution, . . . . .	107,100	172,800
Engineering and contingencies, . . . . .	25,000	27,000
	_____	_____
	\$415,945	\$483,645
Additional cost for iron pipe, . . . . .	76,900	110,900
	_____	_____
	\$492,845	\$594,595

## WATER PIPES.

It will have been noticed in the foregoing estimates of cost, that a very large saving is proposed by the introduction of "BALL'S PATENT INDESTRUCTIBLE WATER PIPE," as a substitute for cast-iron pipe, being incomparably more durable (as there is no rust or decay, but continually growing more permanent), and far superior for cleanliness and purity.

The undersigned, having devoted much attention to the investigation of the merits of this pipe, and having visited works at Jersey City, Brooklyn, and Saratoga Springs, where it has been in service, under from eighty to two-hundred feet pressure for several years, and having at this time charge of water-works where it is now being laid, have no hesitation in recommending its use for your city works, and fully concur in the following testimonials from the intelligent gentlemen named below.

The Water Commissioners of the city of Boston, in their report to the Council in 1848, state, that "pipes formed of sheet-iron, *coated internally with hydraulic cement*, have been recently introduced; and they promise to be highly useful under certain circumstances. When laid in the earth, and in situations exposing them externally to moisture, they are protected by a covering of hydraulic cement, which, besides *preserving the iron against rust*, gives an additional strength to the pipe."

For the benefit of those who have requested information in regard to this excellent article, we insert the following testimonials in relation to its merits:

New York, July 10th, 1853.

MESSRS. BALL AND STEVENS.

DEAR SIRS:—Agreeably to your request, I take pleasure in making such statements, in relation to your Hydraulic Cement Pipe, as now occur to me.

The fact that pipes were made of riveted wrought iron, coated inside and outside with cement, had been known to me for some years, but up to last May my attention was not directed particularly to them. At that time, I undertook to investigate the subject with reference to the adoption of a suitable material for the water pipes of a large work in which I was interested. I confess I was somewhat prejudiced against your method, from its seeming frailty as contrasted with cast iron; and for that reason, the tests applied were more severe than they otherwise would have been.

On 31st May, I witnessed at the Corporation Yard in this city, in the presence of several engineers, a series of experiments on your pipe, as follows, the data of which I extract from notes made at the time:—"Hydraulic Cement pipe, made of No. 20 Iron, 11 inches diameter, 7 feet long, riveted at intervals of  $1\frac{3}{4}$  inches, with rivets weighing three pounds per thousand, lined half an inch thick with Rosendale cement, was subjected by hydraulic pressure to four-hundred pounds to the square inch, and remained under this strain for several minutes without exhibiting any signs of weakness. The weight on the valve was then so placed as to bring the pressure to six-hundred pounds per square inch, but just as the valve rose to blow off, the pipe burst, tearing away the *rivet holes*;" this piece would probably have borne a static pressure of five-hundred and fifty pounds per square inch, without injury. Another piece of similar dimensions, of lighter iron (No. 23.), but riveted at intervals of 1 inch instead of  $1\frac{3}{4}$  inches, was then put in the press, and successively subjected to 480, 500, 600, 700, and 800 pounds per square inch, without sensibly affecting it: the latter pressure was the limit of the capacity of the press; it was not, therefore, known what the piece would have burst with.

The amount of pressure which a wrought-iron riveted pipe would sustain, when made of known stock could be calculated upon data already well authenticated; but the durability of the pipe when in use, could only be determined approximately by analogy or experiment. In the latter part of May last, I saw at Saratoga Springs the main conduit uncovered, which has been in use nearly seven years: this is made of your cement pipe. I broke from the outside, a portion of the cement covering, and found the iron uncorroded and *in appearance similar to a new stove-pipe*: this pipe is 6 inches in diameter. A

specimen from the New Jersey Marshes which had been in use for nearly the same length of time, exhibited the same favorable appearance inside as well as outside.

The difference in the expansion and contraction of the iron and cement, consequent upon changes of temperature, is more or less likely to disconnect them, if in contact; but at the depths which it is necessary to put pipes in the ground, to guard them from frost, any atmospheric changes would scarcely operate—which, in practice is found to be the case.

By your method of working the cement immediately after it is mixed, you avoid altogether the risk of contraction in hardening. The experiments which were made for me at your factory, determined this question conclusively.

As your pipe compared with cast iron is so much cheaper, and the water which passes through it is less affected than that which passes through iron, I have no hesitation in recommending it, where properly made and carefully laid, for all purposes where mains and street-service pipes are wanted.

EDWARD W. SERREL,

CIVIL ENGINEER.

The following is from the Water Commissioners and Trustees of the village of Saratoga Springs, given in 1849, and where the same pipe is at this time in use, and as good condition as at the date of this certificate.

“In answer to the numerous inquiries in relation to J. BALL & Co.’s INDESTRUCTIBLE WATER PIPE, composed of iron and cement, and in use in our village, the undersigned, water commissioners, trustees, and late trustees of the village of Saratoga Springs, take this method of saying that we have perfect confidence in the utility, goodness, and durability of said pipe. The village of Saratoga Springs has some 20,000 feet of this pipe, varying from  $6\frac{1}{2}$  to  $1\frac{1}{2}$  inches in diameter, under a head of about 80 feet. It has been laid since the fall of 1846. Since it was fully completed, it has cost comparatively nothing to keep it in repair; and although some portions are exposed to the frost, it seems to stand well the test, and answer all the purposes for which it was designed and constructed. We believe it preferable to iron pipe—is much cheaper and more durable; and we would not exchange it for any other kind of pipe yet invented, if we could without any additional expense or inconvenience. The water comes through clear and pure; and where we have had any occasion to take any part of it up to improve or alter the grounds, it appeared to be

just as sound and imperishable as the moment it was laid down. This testimony is entirely disinterested, and is now given to avoid the necessity of answering the many calls upon us for information on this subject. We have witnessed, and many of us have superintended, the laying down of the pipe in this village, and watched its operations since, and are perfectly satisfied that we have the best water-pipe ever presented to the public.

*Saratoga Springs, Dec., 1849.*

G. M. Davidson, R. Putnam, N. B. Doe,	Water Com.	R. Gardner, H. P. Hyde, J. L. Perry, J. D. Briggs,	Trustees.
		S. Chapman, J. A. Corey, W. S. Alger, William Cook,	Late Trustees.

“I certify that I was Chief Engineer, having the construction of the above work in charge, and fully concur in the foregoing statement.

“S. R. OSTRANDER, Civil Engineer.”

*Dec., 1849.*

#### ROCKVILLE WATER WORKS.

For the information of those interested in Water Works, we make the following statement:

In the fall of 1847, J. Ball & Co., of New York, laid of their Indestructible Patent Cement Pipes several miles in this village—ranging from eight to three inches calibre. The grounds are broken, through which the pipes are laid: the head of water ranges from light to 140 feet, giving great efficiency to our hydrants and works throughout the village. The pipes are perfectly tight; and we unhesitatingly say that we prefer them to cast iron, and are confident that they will be far more durable; and, from close examination where they have been opened for tapping and branching, we believe them to be truly “indestructible,” besides being clean and pure.

*Agents.—GEO. KELLOGG, Rockville Manufacturing Company; ALLEN HAMMOND, New England Company.*

J. N. STICKNEY.

*Office of the Greenwood Cemetery, April 29, 1852.*

Messrs. J. Ball & Co., laid in the grounds of this institution, two years since, about 800 feet of 8 inch cement pipe, conveying water, forced by a steam pump, to an elevation of 110 feet. It has proved perfectly satisfactory, and is in my opinion preferable, for several reasons, to the best of iron pipes. Having both kinds in use, I do not hesitate from the experience thus far had, to express this opinion.

J. A. PERRY, Comptroller.

In addition to the above testimonials, we can state that, having had experience and personal knowledge in regard to the excellent qualities and durability of the above pipe, we have no hesitation in recommending it to the public.

Starr & Alberts, 122 Nassau street.  
 Frederick Marquand, per H. G. M., Att'y.  
 Janes, Beebe & Co.  
 H. W. Metcalf, 63 and 65 Centre street.  
 Norman White, 111 Fulton street.  
 John J. Merritt, 76 Columbia street, Brooklyn.  
 Platt & Brother, 20 Maiden Lane.  
 Geo. Griswold, South street.  
 J. & J. W. Meeks, 14, 16 and 18 Vesey street.  
 Wm. Gale, 116 Fulton street.  
 J. C. Brown, Builder, 10 Dutch street.  
 Wm. Colgate & Co.  
 Thos. C. Smith.  
 O. R. Burnham, 17 and 19 Broadway.  
 G. B. Hartson, 58 and 60 Vesey street.  
 Wm. W. Campbell, 77 St. Mark's Place.  
 Lorin Brooks, 240 Broadway.

MESSRS. J. BALL & Co.

*Gents.*—Articles have appeared in the Farmer and Mechanic, from Saratoga and Cohoes, on the subject of your Water Pipes; I fully endorse their opinions. Your work for my son's Water Cure, at South Orange, embracing a large amount of four and three-inch pipe, under a head of at least as great as the Croton of New York, shows not only certainty and efficiency, but what

is equally important, perfect purity, which for medical purposes is all-important, and should be considered so for drinking and other uses.

Yours,

SAM'L MEEKER.

*Newark, Jan. 11, 1850.*

In addition to the above, we certify that J. Ball & Co. have inserted pipes for us, of 10 inch bore and less, since the winter of 1844, and that last spring we had over 1,000 lbs. of lead pipe removed, and its place supplied with their pipe. We fully endorse the opinions expressed in the notices above.

BEACH, BROTHERS,

1850.

New York Sun Establishment.

Having, for the past three years, laid many of Messrs. J. Ball & Co.'s Patent Cement Pipes, for the Newark Aqueduct Co., I prefer them to any pipe that I have used, their cost being one-third less than iron pipe, and also being free from wear and rust, and can most cordially recommend them for all aqueduct purposes.

SHELDON SMITH, Superintendent.

*Newark, Jan. 14, 1850.*

CERTIFICATE OF PROF. HORSFORD, HARVARD UNIVERSITY.

CAMBRIDGE, SEPT. 28, 1853.

I have examined, somewhat in detail, the pipe manufactured by Ball & Co., for conveying and distributing water. I have repeatedly attended upon their manufacture, and the inspection preparatory to use. I have farther attended upon the laying down of the pipes, and observed the mode of imbedding in and coating with cement, the connection of sections of pipe, the piercing for lateral service pipes, and, I believe, all the various processes by which the pipes are fitted for use. I have witnessed their service under a pressure of a hundred and twenty feet. I have examined various specimens that have been in use for a period of seven years; and, with one reservation, which is made because I have not had opportunity to examine with sufficient care this branch of the subject, I am prepared to say:

That with strict fidelity on the part of the workmen and engineer, the above kind of pipe may be made and laid down so as satisfactorily to fulfill the general purposes of water distribution.

Where the pipes are liable to displacement or jarring, or sudden shocks, such as are produced by the water-hammer action—when a cock is suddenly closed under considerable head—I am not prepared to say what will be the effect; but

I hope, at an early day, to report upon the result of an examination of the practical working of the pipes under the conditions named.

The advantages of the pipes of Ball & Co. are, that, after a few days of use, the water is transmitted entirely unchanged; the pipes do not corrode and encrust so as to diminish the service capacity; the strength increases with age; and the cheapness will make it possible to introduce water into places where the cost of cast-iron pipes would leave it impossible.

Signed,

E. N. HORSFORD,

*Rumford Professor, Harvard University.*

The pipe manufactured by Ball & Co. is recommended for your use, not only on account of its *economy*, and the increased facilities for making the joints, taps, &c., but on account of its superiority over cast-iron pipe, in causing much less friction to the flow of water, which experiments have fully shown to be the case, and its freedom from the contingencies to which iron pipes are subject, by gradually filling up with tubercles, formed *principally by oxydation of the pipe itself.*

The importance of this question will be more fully illustrated by the following extracts from various reports and statements on this point. E. S. Chesbrough, Esq., the City Engineer of Boston, in his Report to the Cochituate Water Board, in 1852, remarks, that—

“The rapidity with which the interior surfaces of some of the pipes have become covered with *tubercles* or rust, has excited a great deal of interest, and has been the subject of much observation; but the cause of such a wide difference in the growth of these tubercles in different pipes, and in different places, does not appear to be clearly understood. All the large pipes that have been opened, have been partially or entirely covered on their inner surfaces, some with detached tubercles, varying from a half to two and a half inches base, with a depth or thickness in the middle of from one quarter to three quarters of

an inch; and some entirely, to an average depth of half an inch, with a rough coating, as if the bases of the tubercles had crowded together. The smaller pipes all exhibit some action of this kind, but generally to a less extent, as regards thickness, than the larger ones. In one case, however, a four-inch pipe was found covered to a thickness of about one inch. This was in that part of Myrtle street which was formerly called Zinc street, where the entrance to a service pipe was entirely stopped by rust. Wrought-iron pipes fill much more rapidly than cast-iron ones; and in several instances, service pipes made of that metal have, during the last year, become so obstructed as to be almost or quite useless.

"The Jamaica Aqueduct pipe, which was originally ten inches in diameter, has been, in some cases, reduced to eight by tubercles, which, however, are different in form from those in the Cochituate pipes. They appear to lap over each other in the direction of the current; this is very strikingly the case at the commencement of the pipe, as if their form was owing in some measure to the mechanical action of the current.

"Knowing that this subject has occupied much of your attention, that you have consulted articles from various foreign journals that treat upon it, and that Prof. Horsford has it under consideration, no discussion upon the cause or causes of these tubercles will be attempted here."

The following extracts are taken from the last annual report of the "Cochituate Water Board to the City Council of Boston," to show the growing importance of this subject:

"Among the variety of topics noticed in the Report of the Engineer which are well deserving the consideration of the City Council, there is one, in particular, to which we would now call its attention, which we consider to be eminently so. We allude to the effects which are found to be produced on the inner surface of all the iron mains and pipes, by the action of the water. The attention of the Water Board was attracted to the subject, soon after its appointment; for although the pipes had then been in use less than three years, those effects are already quite obvious and striking, and in fact had been noticed some time previous. They have since then been carefully watched, and the valuable assistance of Professor Horsford has been engaged, for the purpose of ascertaining as far as is practicable, their origin, their probable progress for the future, and the means which

might be relied upon, for the purpose of preventing, arresting, or retarding them, and thus obviating the consequences which were likely to be the result. The two communications of Professor Horsford on the subject, which we beg leave to annex to this report, have described with so much minuteness and clearness the present appearance and state of the interior of the mains and pipes, as does also the report of the City Engineer, that it is rendered entirely unnecessary for the Board to repeat the description, and they would therefore refer the Council to those communications. It is presumed, also, that the members of the Council are generally acquainted with those facts.

"The effects to which we now allude, are the peculiar changes which have been produced on the iron itself; and they consist in

"1. The absorption of the iron in certain places, and the formation in its stead of a substance resembling plumbago.

"2. The gradual development of local accretions or tubercles, in the interior of the pipes, by which the flow of water is impeded, and their capacity diminished, so that the object for which they were laid becomes imperfectly accomplished, and an apprehension is excited that they may be so far closed up as to be useless hereafter.

"This subject has received but little scientific investigation, till within a few years, notwithstanding its very obvious importance, and although the evils must have existed ever since cast iron has been used for such purposes. It is one, however, of no little importance to the city, as there is involved in it the question of the present and future capacity of all the iron pipes which have been or are to be laid, at no small expense, and of their consequent adaptation to the purpose for which they are used, and also of their ultimate durability. The Water Board have therefore thought that it would be interesting and useful to lay before the council somewhat in detail, not only the present condition of the pipes belonging to the Water Works of this city, in relation to the subject, but also the result of such inquiries as they have been able to make into the extent of the same evils in other places, and the efforts which have been made to ascertain their nature and origin, and to provide a remedy for them, and the success of those efforts.

"The first notice taken of this subject which we have seen, appears in the transactions of the French Academy of Sciences, for the year 1836. (*Comptes Rendus*, v. 3, p. 131.) It is a note by *Mr. Vicat* on the subject of a coating to prevent the development of tuberculous accretions in cast-iron pipes for conducting water. He states that a report printed at Grenoble, November 22, 1833,

by order of the Municipal Council, called the attention of the public to the rapid, as well as unforeseen, filling up of the large cast-iron main, of the *Chateau d'Eau*, in that town. The formation of numerous tubercles of hydroxide of iron, began to show itself shortly after the water was let on, by a perceptible though slight diminution of the discharge. The development of the accretions, however, as was proved by many accurate measurements, soon increased so much, that the supply of the *Chateau*, which had been in 1826 about 1,400 litres (about 370 wine gallons) a minute, was gradually reduced in 1833 to 720 litres (about 190 wine gallons), showing a loss of nearly one half. A good deal of alarm was excited by it, and an attempt was immediately made, by eminent chemists, to ascertain the cause, and reconcile the phenomenon with various theories. A commission, consisting of engineers and others, was also appointed, which discussed, at Grenoble, the means of destroying this kind of ferruginous vegetation (as it is called in the report), or of arresting its progress. In the meantime *new measurements indicated, that in less than five years the pipes would probably be so obstructed that the water would cease to flow through them.* Two members of the Commission, Messrs. Guemard and Vicat, Engineers in chief, being persuaded that the tubercles were formed at the expense of the castings, applied themselves to the discovery of some coating which would be, at the same time, cheap, indestructible, and capable of preventing oxydation. After two years of experiments, they considered it sufficiently proved, that hydraulic cement is of all compositions combining facility of application and cheapness, that which adheres the best to the casting, is the most indestructible, and prevents most effectually all oxydation and consequent formation of the tubercles."

"In 1837 the subject attracted the attention of the *British Association for the Advancement of Science*; and under its auspices a very elaborate investigation of the action of air and water, whether fresh or salt, clear or foul, and at various temperatures, upon cast iron, wrought iron, and steel, was made by Mr. Robert Mallet. Mr. Mallet commenced in 1838, and continued until the year 1843, a very complete course of experiments on the subject."

"In his first Report, which is devoted to the consideration of the then existing state of chemical knowledge of the subject at large, he remarks, that notwithstanding the innumerable uses to which iron had been applied, for the purpose of supplying the social wants of man, during the preceding half-century, yet our information on the subject of its durability, and the causes likely to impair or promote it, was scarcely more advanced than it had been

twenty years previously ; and that while the chemist was not precisely informed as the changes which air and water produce on it, the engineer was without data to determine what limits the corroding action sets to its durability. Nor was it known with certainty, what properties should be chosen, in wrought or cast iron, that its corrosion might be the least possible under given circumstances. Neither was our actual knowledge more advanced as to the variable effects of corrosive action, on the same iron, of different waters, such as are commonly met with, containing their usual mineral ingredients in solution."

" The investigation was, therefore, undertaken for the purpose of throwing light on these topics ; and there was of course involved in it a great extent of inquiry into the durability of the metal, the forces which were likely to impair it, the mode in which these forces would act, what would be their results, and the means of arresting their progress.

" The Board can merely state some of the general laws, regulating the action of fresh water on iron pipes, which Mr. Mallet considers as previously known, or established or confirmed by his experiments.

" He found that *any sort of iron, cast or wrought, corrodes when exposed to the action of water holding air in combination*, in one or other or some combination of the following forms, viz.: 1. *Uniformly*, or when the whole surface of the iron is covered uniformly with a coat of rust, requiring to be scraped off, and leaving a smooth, red surface after it. 2. *Uniformly with plumbago*, where the surface, as before uniformly corroded, is found in some places covered with *plumbagenous* matter, leaving a *piebald* surface of red and black after it. 3. *Locally*, or only rusted in some places, and free from rust in others. 4. *Locally pitted*, where the surface is left as in the last case, but the metal is found unequally removed to a greater or less depth. 5. *Tubercular*, when the whole of the rust which has taken place at *every point* of the specimen has been transferred to one or more particular points of its surface, and has there formed large projecting tubercles leaving the rest bare."

" *Fresh water may hold so much combined air (not to speak of carbonic acid), as to act more rapidly than sea water.* Carbon, as it is known, exists in iron as diffused *graphite* in a crystalline form, and as *combined carbon* : the dark gray and softer irons contain more of the former; the lighter and harder irons more of the latter."

" The *rate of corrosion* is a decreasing one, at least when the plumbago and rust first formed has been removed. When, however, this coating remains untouched, the rate is much more nearly uniform, and is nearly pro-

portional to the time of reäction, in given conditions. In some cases even where the coating had been removed, an increment in the rate had taken place. And it is observable that this almost uniformly occurred in those specimens which had the smallest amount of corrosion at their first immersion. Thus there was a tendency to a greater equality in the index of corrosion in all the varieties of iron at the second than the first immersion."

"The size, and perhaps the form, of iron casting, forms one element in the rate of its corrosion in water. Because the thinner castings having cooled much faster and more irregularly than the thicker, are much less homogeneous, and contain veins and patches harder than the rest of their substance: hence the formation of voltaic couples and accelerated corrosion.

*"He estimates that from three-tenths to four-tenths of an inch in depth, of cast iron one inch thick, and about six-tenths of an inch of wrought iron, will be destroyed in a century, in clear water."*

"As to the nature and origin of the peculiar change which takes place in the conversion of part of the metal into an entirely different substance, but little information, beyond what was already known, can be obtained from these reports. It is stated in the introductory one, before the result of the experiments was ascertained, as a fact first observed by Dr. Priestly, that cast iron being immersed in sea water for a length of time, has its metal wholly removed, and becomes changed into a substance analogous to plumbago, mixed with oxide of iron, which frequently, though not invariably, possesses the property of heating and inflaming spontaneously, on exposure to air; but that it is yet by no means clear how it is produced, what is its precise composition, and to what is owing its rise of temperature on exposure to air; that malleable iron, under circumstances but little understood, is also subject to this change; and also, from various statements of others, it would seem that both malleable and cast iron are affected in the same way, when immersed in water holding in solution alkaline or earthy salts or acids.

*"The subsequent experiments throw no new light on the cause and nature of this singular phenomenon. They show, however, that the same effect is produced by the action of air and fresh water; and this is too well corroborated by our own experience."*

"The important problem of preventing the corrosive action of the water, by coating the interior surface of the pipe, was a principal object of Mr. Mallet's experiments."

"The various results of Mr. Mallet's experiments are exhibited in a full series of tables, which present to the engineer, as he thinks, 'sufficient data to

enable him to predict the term of durability, and allow for the loss by corrosion of iron in all conditions, when entering into his structures.'

"The last information to which we shall refer on this subject, is contained in a paper on *Tubercles in Iron Pipes*, by *M. Gaudin, Engineer of Bridges and Roads*, published in the *Annales des Ponts et Chaussées*, for November and December, 1851. He states that the iron conduit at Cherbourg, constructed between the years 1836 and 1838, of white casting, nearly  $1\frac{1}{2}$  miles long, had become everywhere coated with tubercles, which in some places had an elevation of from 1.575 to 1.968 inches, so that the orifice of the pipe, which was when laid about 7 inches in diameter, had been reduced to less than one-third its original section. The consequence of the diminution of the orifice, joined to the enormous loss of head occasioned by the additional friction, had deprived many of the work-shops at the end of the conduit of a supply, prevented the simultaneous playing of the fountains, and made the supply of the grand reservoir impossible, or very feeble.

"The tubercles were very broad at their base, and very strongly adhering to the surface of the pipe, and could not be removed, except by heating the pipe to a red heat, or by a forcible action of an instrument. They were of a greenish brown color, and testaceous structure, and on exposure to the air, assumed the color of yellow ochre, a sure sign of the oxydation of part of the iron which entered into their composition. Their density was almost 3.362. A chemical analysis gave the following results:—

"Peroxyd of iron, 96 to 98.

"Silex and Alumine (argel) 4 to 2.

"Chlorid of Sodium—traces.

"Sulphate of Iron—traces.

"They were, therefore, almost entirely free from (at least as far as regards the iron which they contained) the elementary matters contained in the water in solution—and, indeed, they were not derived from substances which it could hold in solution. The water was free from color, taste or smell, and its specific gravity nearly that of pure water. It showed on analysis by chemical tests,

"A very small quantity of carbonic acid.

"A small quantity of calcareous earth.

"A small quantity of sulphate of soda.

"A positive quantity of chlorid of soda.

"Little or none of the metallic salts.

"And little or no iron.

"A more recent analysis of the water, taken before its passage through the conduit, showed its density to be scarcely different from *distilled water*; to reagents it only showed chlorids, and those, chlorids of sodium; there was no trace of lime, nor sulphates, nor iron.

"He considered it certain, that the iron in the tubercles was to be attributed, exclusively, *to an alteration which had taken place in the pipes themselves, no matter what the casting might be, whether white or gray.* And as, notwithstanding this alteration, there could not be seen in the pipe, even with a glass, after it had been well rubbed, any difference between its texture and that of new casting, he concludes, that the deterioration must have taken place over the whole surface indiscriminately, in the same way."

"In reference to the obtaining some remedy for the evil, he observes, that waters the most pure and most proper for the ordinary necessities of life, afford no exemption, since it appears invariable, that the tubercles are in an especial manner developed by the presence of very small quantities of sea salt, which almost all waters contain. And that chemists and engineers have therefore recommended the forcing of linseed oil by great pressure into the metal, and also coatings of mortars and hydraulic cements and bituminous coverings."

"The foregoing statement contains a very brief analysis of the investigations which have been made, in other places, of the nature, origin, and mode of remedying the evils now under consideration, as far as they have come to our knowledge. We annex to it the able and interesting communications of Professor Horsford, and refer to the report of the City Engineer, to show the extent of our own experience in relation to them. It has been hoped that by bringing to the notice of the Council all the facts which we have been able to accumulate, and offering even an imperfect sketch of the researches hitherto made on the subject, we might enlist the attention not only of those who are similarly interested with ourselves, but also of men of science, and of those who are engaged in the production of the metal itself, or in the great variety of manufactures and constructions in which iron is employed. And that, if this object could be effected, it might be the means of ascertaining hereafter some mode, either of preventing the evil in its origin by improvements in the castings; or, of arresting or retarding its further progress, *by the intervention of some preparation for covering and protecting the surface;* or, of obtaining a temporary remedy by providing a mode of removing the obstructions as they from time to time appear.

"Undoubtedly the most important change which takes place on the inner surface of the pipes, as far as relates to any immediate results, is the production

of the accretions. The formation of plumbago or something like it, in the place of the iron which has been absorbed, does not, indeed, protect the metal beneath it, and the action continues, perhaps even with a slightly accelerated force; but, according to the French and English authorities, its progress is so slow that many years must elapse before any serious consequences from it alone, would be likely to happen. It is probable that the only way to prevent this action, will be found in coating the surface with some composition which will shield it."

*"But with regard to the accretions, their growth has been more rapid and important, so much so that our 36 inch and 30 inch mains have become already, in consequence of the actual diminution of their area and also of the additional friction which has been occasioned, scarcely superior in capacity to those of 34 and 28 inches having a clean surface; and we have had sufficient experience on the subject to convince us of the impolicy of making use of wrought-iron service pipes at all, or of cast-iron ones of less than 4 inches in diameter."*

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" CAMBRIDGE, JAN. 14, 1852.

" THOS. WETMORE, Esq.

*"President of the Cochituate Water Board.*

" DEAR SIR,—In reply to your favor of the 5th instant, in relation to the accretions in the Cochituate iron mains, I have to regret that my investigations thus far have thrown but little light upon the question of most importance; to wit, *How far will these accretions extend?*

"A brief statement of the present condition of the pipes will show the bearing of this inquiry.

"At the two points near Dover street, where one of the main iron pipes was taken up for repairs in the last autumn, there were found upon the interior surface of the pipe, *nodules varying from half an inch to three inches in diameter, at the base, and having a height of from one quarter to a little more than half an inch.* Some of them were of a reddish, others of a dirty yellow color, and those of each color invariably in a group by themselves. They presented concentric structure within, and rested in many cases upon slightly elevated portions of the surface of the pipe. These elevated portions were co-extensive with the inferior surface of the nodules, were of a dark brown color, and crumbled at once to powder upon being scratched with a knife.

"Portions of the surface of some sections of pipe were quite free from accretions. In some areas, the accretions were all small; in others most were

large. *There seemed to be no tendency among them to gather upon the bottom rather than upon the top and sides.* \* \* \* \* \*

“The suggestion that the accretions might be due to the growth of some kind of vegetation in which were lodged particles of the ochreous matter in suspension in small quantity in the Cochituate water, and which gives to it its occasional faint wine color, which is found on the bottom of the tunnel, and which accumulates in the filters—*was not sustained by microscopic examination.* \* \* \* \* \*

“There are reasons for believing the slight elevations of surface observed immediately beneath the accretions, to be due to changes in the texture of the iron arising from the growth of the accretion, *and not to an original irregularity of the casting; and further for believing that the accretions are indebted for their iron to the surface upon which they rest, and not at all, or but very slightly, to the water which flows over them.*

“*I have wrought-iron pipes of 1 1-2 inches calibre, which are coated with accretions interiorly, and which in 12 months have been eaten through, from within outward, by the circulation of cold Cochituate water. I have others of the same diameter, which in 3 months have been eaten through by the circulation of hot Cochituate water.*

“*I have another pipe, 1 ineh in diameter, which in 12 months was so nearly closed by accretions throughout its entire length, that it was removed because it ceased to serve water.*”

“The solicitude lies in two directions. In the first place, the accretions diminish the serving capacity. Taking the present average thickness of the incrustation at 3-8 of an inch, the serving capacity of a pipe 36 inches in diameter is reduced by the amount of an area of 42 3-8 square inches, which is equal to a cylindrical pipe 7.3 inches in diameter. If we conceive the accretion to go uniformly forward at this rate of 14 1-8 square inches per annum, it would become a matter of *immediate grave consideration.* In the second place: *the accretions are formed at the expense of the iron upon which they rest. With their increased thickness will come, at a remote period, diminished strength of the iron.*

\* \* \* \* \*

“I am, very respectfully,

Your obedient servant,

“E. N. HORSFORD.”

The foregoing statements have been given somewhat at length because we are impressed with the importance of this subject to all present or prospective plans for supplies of water. Our own conclusions have been derived from careful examinations of this kind of pipe, which have satisfied us of its value; and we would respectfully suggest to you the propriety of appointing a committee to examine the pipe now in use and in progress of construction in several parts of the country, before any system of distribution is finally adopted.

## RESERVOIRS.

From the surveys made by the undersigned for the State in 1848, it was ascertained that the flow of the Honeoye outlet did not exceed 4,000,000 gallons per day, in the dry seasons. It was also found that by lowering the surface of Hemlock lake 6 inches (using it as a storing Reservoir) a daily supply of over 2,000,000 of gallons would be obtained for about five months.

It is evident either that the whole supply of the outlet may be taken, by compensating the mill privileges on its banks; or the lake itself used during the dry seasons as a storing Reservoir. We have, however, advised the plan of a storing Reservoir at Henrietta, on account of its proximity to the distributing Reservoir, in case of accident to the line of conduit, and its purifying effect on the water before its immediate use.

Such a Reservoir may be constructed in Henrietta, at moderate expense, several suitable locations being available.

## THE DISTRIBUTING RESERVOIR

Is proposed to be located on the high grounds south of the city and east of Mount Hope, covering an extent of *four* acres, with a surface elevation of 100 feet above the Erie Canal, the depth being 25 feet. If Plan No. 3 or 4 should be adopted, an additional cost for filtering arrangement will be necessary on account of the quality of the water proposed to be used under these Plans. The quantity contained will be equivalent to four weeks' supply at present and two weeks' supply 12 years hence.

The elevation of this Reservoir has been placed at 100 feet above the Canal, to provide for sufficient supply and head for domestic uses, and especially for protection in case of fire. The loss of head through a connected system of mains and pipes is considerable; and, as the elevations of the streets in several parts of Rochester are about twenty-five feet above the Canal, no system can be recommended which does not provide for every locality. Some idea of the *loss of head by friction* in distribution pipes may be obtained from the following extract from a report of G. R. Baldwin, Esq., Civil Engineer "on supplying the city of Quebec with pure water," made in 1848.

"At Philadelphia the water will rise from a hose attached to a fire plug in the street, at the extreme point of delivery during the *night*, to the height of about *forty-five or fifty feet*; during the *day*, when the consumption of water is very great, *twenty to thirty feet*. Head of water in this case was probably not far from *one hundred feet*."

The *location* of this Reservoir has been adopted at the point named, although involving some additional expenditure for

want of a suitable location as to size and elevation, nearer the Genesee River, or west of Mount Hope.

#### DISTRIBUTION.

The system of Distribution commences at the Distributing Reservoir with an 18 inch main, through St. Paul street to Erie Canal, and thence across the Canal and River to the corner of Exchange and Troup streets. A 16 inch main will be laid through Exchange to Buffalo streets, the continuation in St. Paul street north being a 12 inch main. Stop-cocks at the main branches have been included in the estimates, with hydrants every two blocks.

The system of mains and pipes will provide for an eventual supply of 2,500,000 gallons, of which 1,500,000 will be used on the west side of the Genesee River. The first class, embracing 14 miles, and 11 miles of the second class, will supply *the present wants of the city*, the entire arrangement being shown in the following statement:

Distributing Main, . . . .	18 In. Diameter, . . .	10,000 feet.
" " . . . .	16 " "	3,700 "
" " . . . .	12 " "	11,900 "
" Pipes, 1st class,	8 " "	10,450 "
" " "	6 " "	32,580 "
" " "	4 " "	18,100 "
" " 2d class,	8 " "	26,300 "
" " "	6 " "	14,050 "
" " "	4 " "	63,260 "
" " 3d class,	8 " "	1,700 "
" " "	6 " "	16,650 "
" " "	4 " "	80,250 "

*Summary.*

18 In. Main,	.	.	.	10,000 feet.
16 "	"	.	.	3,700 "
12 "	"	.	.	11,900 "
8 " Pipe,	.	.	.	38,450 "
6 " "	.	.	.	63,280 "
4 " "	.	.	.	161,610 "

It is believed that the foregoing Report comprises the principal features of all the sources of supply available in the vicinity of Rochester. The time which has been occupied in making the necessary instrumental examinations, and arranging the several plans of machinery, has been somewhat limited, and many of the details remain in manuscript, which can be more fully perfected hereafter; in case either of the proposed plans is adopted. These, with any other information on this subject, in our possession, are at your service.

With regard to the estimates made, it is proper for us to say, that reliable and experienced parties have intimated their willingness to contract for the work at the prices named, investing a liberal proportion in the stock of the Company at par value.

Respectfully, your obedient servants,  
 CHARLES B. STUART,  
 DANIEL MARSH,  
 FIRM OF STUART, SERRELL & Co.,  
*Civil Engineers, New York.*

NEW YORK, Oct. 1, 1853.



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